Recent Advances in Cloud Computing Applications and Services

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Abstract: This paper gives an overview of cloud computing applications including its particular characteristics, traits and issues. Cloud Computing models also covering mobile cloud computing using HTML 5 as well as security concerns and fault management are addressed. The particular enhancements that using mobile internet devices can bring to cloud computing are discussed. The differences between traditional Cloud Computing, IT Outsourcing , Client-Server, Fixed-line and Mobile Cloud Computing models are compared.

Index Terms: Cloud Computing, Mobile Cloud Computing, Fixed-line Cloud, IT Outsourcing, Client-Server, Cloud Applications, Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS).

I. Introduction

Today the use of cloud computing applications is mushrooming at an ever increasing rate. But what exactly is cloud computing? "Cloud computing is a technology that allows the users to access software applications, hardware, storage, computing processes directly from the web." [1] This is no doubt being helped by the prevalence of mobile devices such as smart phones and tablets with fast internet access using 3G and 4G communications links in the form of mobile cloud computing [2]. These devices have direct, fast and cheap links to the internet which makes it easier to upload and download programs and applications onto the internet and on online network storage services. Often this mobile link provides a superior and faster link to the internet cloud than using a fixed broadband access. This paper describes the various major applications of cloud computing along with its pertinent characteristics. This paper is an extended version of the invited keynote paper [3] published in the International Conference on Cloud Computing and eGovernance - ICCCEG 2013.

II. Cloud Computing Applications

Cloud computing applications are intimately linked with mobility of the user, this may involve international travel. The user wants a seamless integration of services using multiple devices often from multiple locations. The user wants convenience and to carry the minimum amount of hardware. Loss of hardware storage devices may also be an issue. Thus applications that cater for these needs have a special appeal. Security applications, disaster relief, crowd computing involving social networking [2] are prime candidates for adoption of mobile cloud computing applications. Both Apple and Google provide cloud applications, such as Apple's iCloud and Google's mobile email service.

The adoption of cloud computing has not been as fast as mobile telephony. Khan *et al.*, [4] mentions that by 2014 there is expected to be about 1 billion mobile cloud services subscribers, this, however, only represents 19% of mobile subscribers. The main reason for this slow adoption has been due to security concerns. Fig. 1, below illustrates how security concerns can be addressed to provide a very secure cloud computing platform.

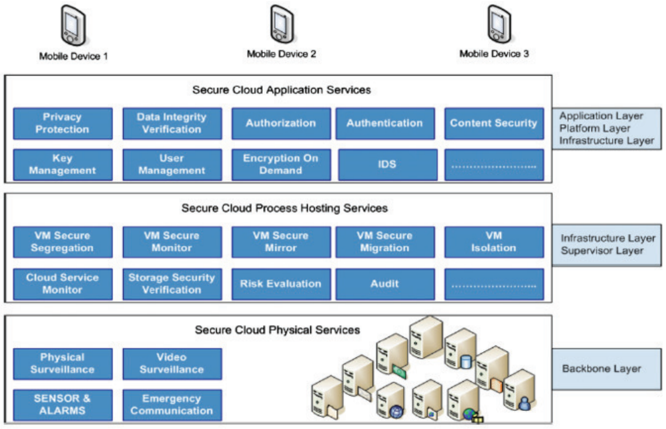


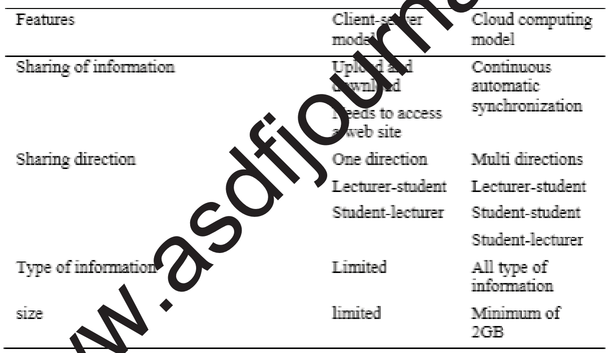
Fig. 1. Security Services on Different Layers of Cloud Computing [2]

Many cloud applications also request and send location data. This sensitive information of the user also needs to be "cloaked" or hidden. This can be implemented as an "in-device" service [4]. Even though end-to-end security may be available when utilizing cloud computing, the issue of who is responsible for "personal data" is a very important issue. This is discussed in length by Hon *et al.* [5].

[5] conclude that an end-to-end accountability approach has to be taken. Where data is not processed then an intermediary rôle of neither data controller nor processor should also be adopted, like the action of a host.

Cloud computing is particularly suited for distance e-learning. A comparison between the client-server model and the cloud computing model is shown in Table 1 [1] with regard to this.

Table 1. The features of the two computing models



Features	Client-server model	Cloud computing model
Sharing of information	Upload and download Needs to access a web site	Continuous automatic synchronization
Sharing direction	One direction Lecturer-student Student-lecturer	Multi directions Lecturer-student Student-student Student-lecturer
Type of information	Limited	All type of information
size	limited	Minimum of 2GB

Cloud computing can be offered either as "SaaS (Software as a Service) such as data storage, computing power and or as PaaS (Platform as a Service), such as a web development platform." [1].

Table 2 [6] summarizes the essential requirements of security, privacy, availability, auditing, flexibility, archiving, quality of service and scalability. Table 2 was derived from case studies in the domains of Government Applications, Large Scale Computations (Business Intelligence Systems), Financial Services, Healthcare Applications and Online Entertainments.

Table 2. Requirements Summary [6]

	Governmental Applications	*Large-Scale Computations*	*Financial Services*	*Healthcare Applications*	*Online Entertainment*
Archiving	High	Low/Medium	High	High	Medium
Audit	High	Low	High	High	Low
Availability	Medium/High	Medium	High	High	High
Flexibility	Medium	Low	High	Medium	Low
Privacy	High	Low	High	High	Low
Security	High	Low	High	High	Medium
QoS	Medium	Medium	Medium	Medium	High
Scalability	Medium	High	Medium	Medium	High

Digital Library Applications are discussed in depth in [7]. [8] discusses using cloud computing to implement a distributed geographical information system platform. Table 3 [9] summarizes the main policy and applications of cloud computing in large-scale organizations.

Table 3. Main Policy and Applications of Cloud Computing in Large-scale Organizations [9]

	Enterprises	***Cloud Offerings***	***Types of Service***
Major Foreign Enterprises	Google	Goole App Engine Platform for web apps	Delivery and deployment platform (App Engine) and productivity tools (Google Apps). Low-cost hardware, scalable software infrastructure, innovative applications. Easy to build, maintain and scale.
	Microsoft	Online Services Windows/Office Live Windows Azure Platform	Via internet to build cloud computing platform. Connect the billions of desktop and explore to a strong cloud network. Software + Services strategy: future is a combination of local software and Internet services.
	Amazon	Elastic Compute Cloud and Simple Storage Service	Through its Amazon Web Services (AWS) products, offers a pay-as-you-go access to virtual servers and data storage space
	Salesforce	On-line CRM services	Based on network, advocating NO Software.
	HP, Intel, Yahoo	The plan of Cloud computing trial platform	Open source software; integrate with the Internet; eliminate data intensive research computing and business computing in a variety of obstacles, promote open collaboration.
	SAP	ERP software based on cloud computing	End-user applications delivered as service, instead of On-premise implementation.
Major Domestic Enterprises	Qihoo, Kingsoft, etc.	"Cloud Safety"	Cloud safety via the network of plenty of End- cloud customer computers to detect abnormal software actions. The more cloud node users there are, the more the safety will be.
	Alibaba	Ali-software	E-commerce business based 'SaaS' and 'PaaS' models.
	21vianet	Distributed IDC sources and CloudEx	Include complete internet host computer CloudEx Computing Service. Cloud security services, data backup for Individuals and enterprises to the Internet
State policy about cloud computing and major collabora-tive research institutions	The policy "*Pilot Program of Cloud-Computing Service Innovation*" demonstrated Beijing's vision and determination of pushing forward Cloud-Computing in China, in which Beijing, Shanghai, Shenzhen, Hangzhou and Wuxi have been chosen as the first wave pilot cities in the program. IBM in North Carolina and Tokyo's cloud computing data centres; IBM Innovation Center in Beijing, China, the establishment of IBM Greater China Cloud Computing Center; Electronics Research Institute and Guangdong Dongguan Songshan Lake Science and Technology Industrial Park in cooperation to invest in cloud computing platform; Ali Baba and Nanjing Municipal Government: E-commerce cloud computing centre.		

It should be noted that the idea of cloud computing was proposed jointly back in 2007 by IBM and Google [10].

Smart Mobile Devices [11] can use sensors that make applications context aware, which reduces user input. Mobile Applications can be enhanced with REST (Representative State Transfer) based cloud computing technologies to create applications that exceed the capabilities of traditional mobile devices. Combining these technologies creates the opportunity to develop a completely new paradigm of consumer software applications.

The need for speed can easily be achieved by adopting the platform of cloud computing. This is realized as a parallel multiple pipelined architecture which is shown in Fig. 2 [12].

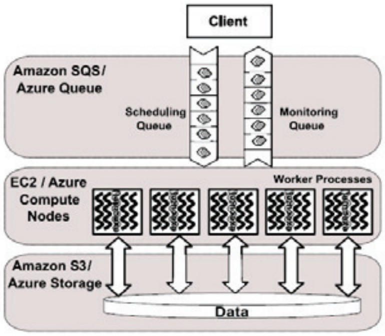


Fig. 2. Classic Cloud Processing Model [12]

Recent advances delivered by HTML 5 are now being exploited in implementing efficient mobile cloud computing applications. Some of the features present in HTML 5 are shown in Table 4, below.

Table 4. Contribution of HTML 5 Features in Dealing with Mobile Device's Limitations [13].

HTML5 Features	**Energy efficiency, battery life**	**Bandwidth networking functionality**	**Processing power, memory**	**Screen size**	**Data entry capabilities**
2D Vector Graphics (SVG)				√	
2D Programmatic API, HTML <canvas>		√	√		
Graphical effects				√	
Downloadable fonts			√	√	
Video and audio playback			√		
New types of form controls		√	√		√
Touch-based interactions, Vibration API				√	√
Device information			√	√	√

, CSS-based adaptation					
Bidirectional connections		√	√		
On-line state		√			
Application Cache, Widgets		√			
Page visibility detection		√	√		
Battery status	√				
Threading			√		

[14] describes three types of cloud computing:

“All functions are provided to users in form of services in clouds, that is X as a Service (XaaS). Above the three types of cloud services are Infrastructure as a Service, Platform as a Service and Software as a Service.

Infrastructure as a Service (IaaS)**:** Users will deploy processors, storage systems, network and other fundamental computing resources, and run operating system and applications software according to their own willing.

Platform as a Service (PaaS): Users write the application using programming languages and tools supported by providers, and run it on cloud platform.

Software as a Service (SaaS): Software providers run programs on cloud computing facility, and users use these programs through a variety of thin client interface by client devices. There are three types of cloud application instances corresponded with three types of services: infrastructure for cloud services, platform for cloud services and application for cloud services.” [14]

These three types of cloud computing models may be summarised by Figure 3 below.

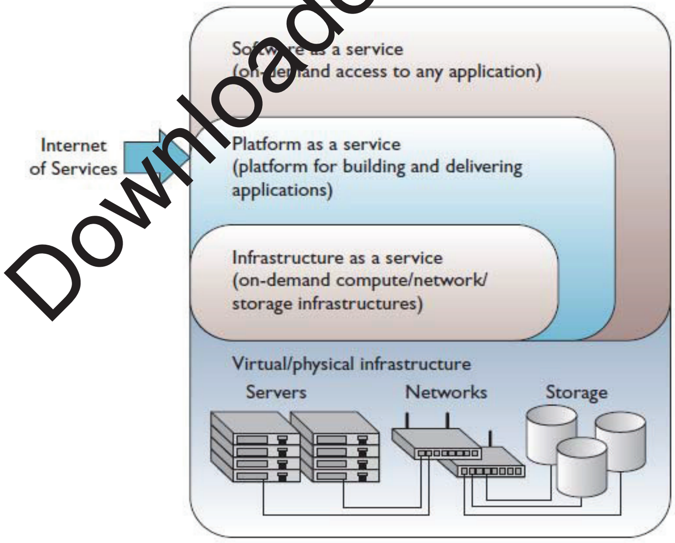

Software as a service
(on-demand access to any application)
Internet of Services
Platform as a service
(platform for building and delivering applications)
Infrastructure as a service
(on-demand compute/network/ storage infrastructures)
Virtual/physical infrastructure
Servers
Networks
Storage

Fig. 3. Cloud Computing Model for the Future Internet of Services (IoS) [15]

It is important that for future IaaS cloud services, the model is able to both absorb and deliver elastic services and workloads. The IaaS model “providers must support dynamic service provisioning; quality-of-service (QoS) and service-level agreement (SLA) negotiations; service scalability; service monitoring, billing, and payment; and context-aware services.” [15]

With concerns for security ever increasing globally, mobile cloud computing for biometric applications is a rapidly expanding area of application [16]. Fig. 4 shows how important biometric feature vectors may be extracted and processed by parallel cloud computing to increase the speed of execution. This is important in arriving at a near real-time decision in matters of security.

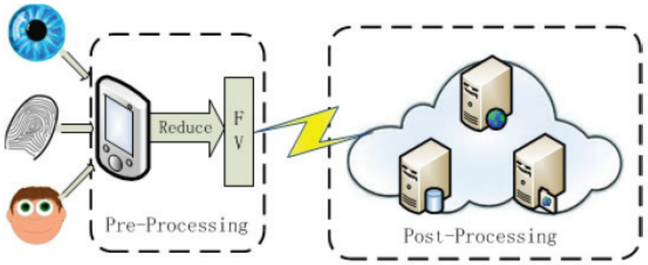


Fig. 4. Example of Mobile Extracts Feature Vector and Offloads Recognition Task to the Cloud [16]

Keeping the data secure requires the use of fast and efficiently generated strong public keys. [17] describes the application of elliptic curve cryptography for securing cloud computing applications through the use of strong public key encryption to model a secured cloud application platform.

[18] offers a novel and extended cloud computing application architecture which has taken into consideration features provided by both IBM and NIST and extended them. This is shown in Fig. 9.
With the prevalence and adoption of QR codes, it is very important to be able to process these in near real-time as possible. [19] offers an approach where the QR code has been used as an image while partitioning and executing the data as a stream through a mobile cloud computing environment. Fig. 5 shows the superior performance in terms of images processed per second if the images are first partitioned and then processed via cloud computing.

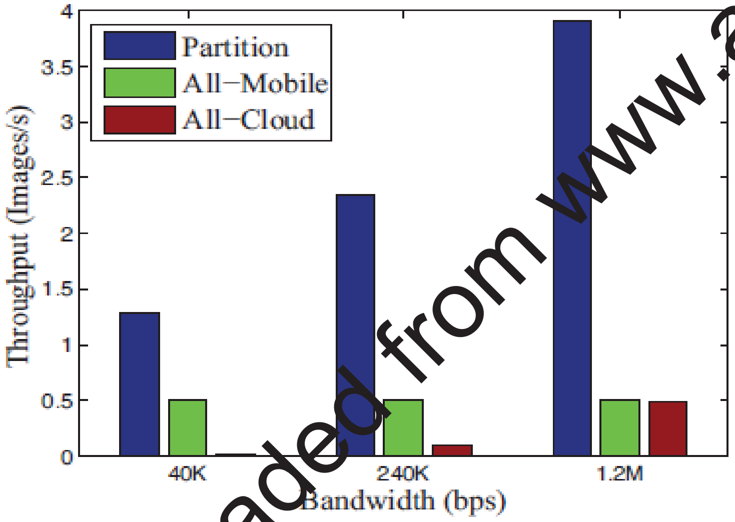
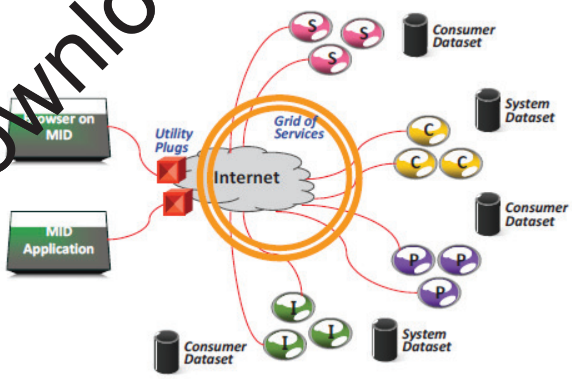


Fig. 5. QR-Code Recognition Performance through various Platforms [19]

Mobile Internet Devices (MID) can enhance their limited computational power by offloading computational tasks onto the cloud. Fig. 6 shows cloud computing applied to MID.



Cloud services can thus provide rich functionalities to MIDs by utilising the powerful internet connectivity of the mobile devices [20].

It is important to take into account how faults are to be handled. [20] addresses this in cloud computing by the adoption of an autonomous fault manager module. Fig. 7 shows the use of blocks with functionalities of ‘identifier’, ‘detector’ and ‘determiner’ in the autonomous fault manager.

Fig. 6. Overall Architecture for CC Applied to MID [20]

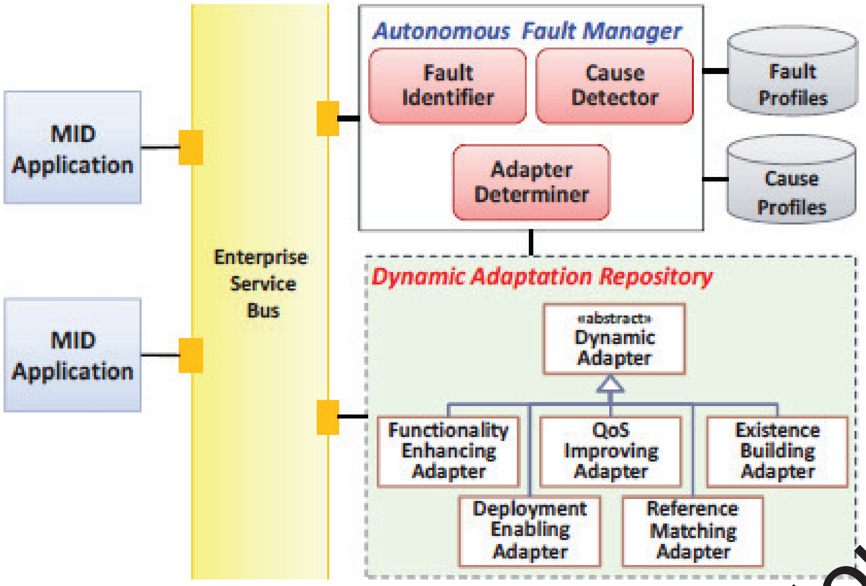


Fig. 7. Architecture for Fault Management [20]

[20] has proposed six essential and key methods to be adopted in the efficient and smooth running of Cloud Computing applications, these are: "capturing commonality into cloud service, design for adaptability, architecting thin-client methods to ensure high QoS, monitoring services, and autonomous fault management." Adopting this strategy will reduce potential future technical problems.

Libraries are also adopting cloud computing to offer their services. An earlier paper [21] published in 2011 discusses offering medical library services utilizing the cloud.

[22] discusses "Cloud Libraries" with special emphasis on how cloud computing may be used to implement "green libraries" with considerable reductions of carbon emissions compared with on-premise delivery using three Microsoft Applications (Exchange, Sharepoint and Dynamics CRM).

[23] discusses the adoption of cloud computing by small and medium enterprises in the North East of England. Fig. 10, shows the decision making points that need to be considered for the adoption of on-demand computing services.

The ability to deliver ever increasing bandwidth services will require for the foreseeable future the adoption of an optical network [24]. An example of such a cloud network implemented using various optical networking technologies is shown in Fig. 8, below.

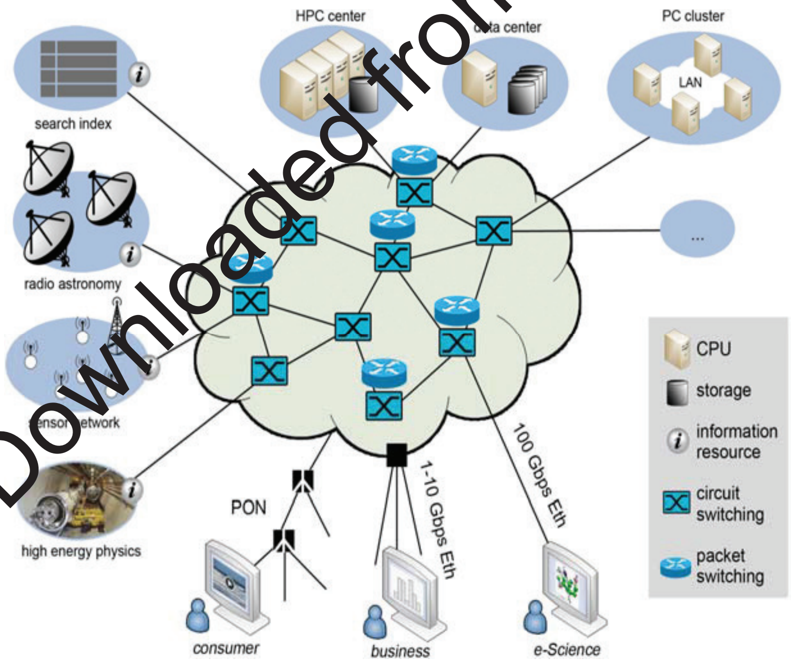


Fig. 8. High bandwidth cloud computing applications using optical networking [24]

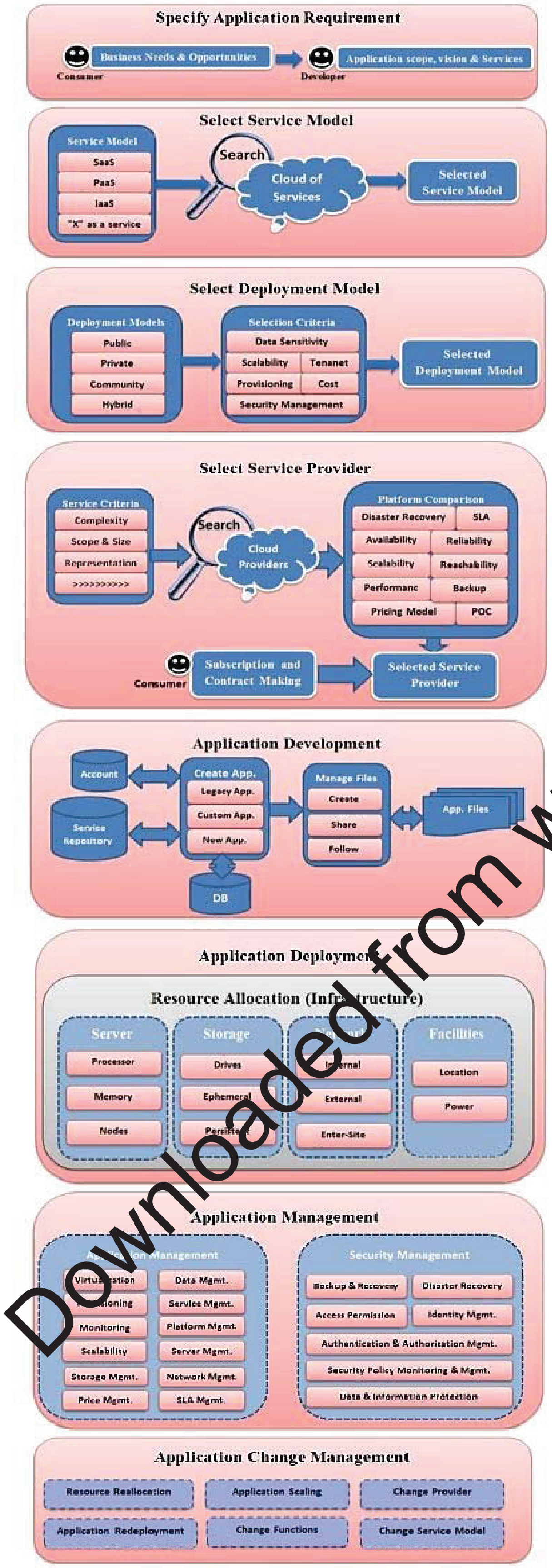


Fig. 9. Hassan's Cloud Computing Architecture [18].

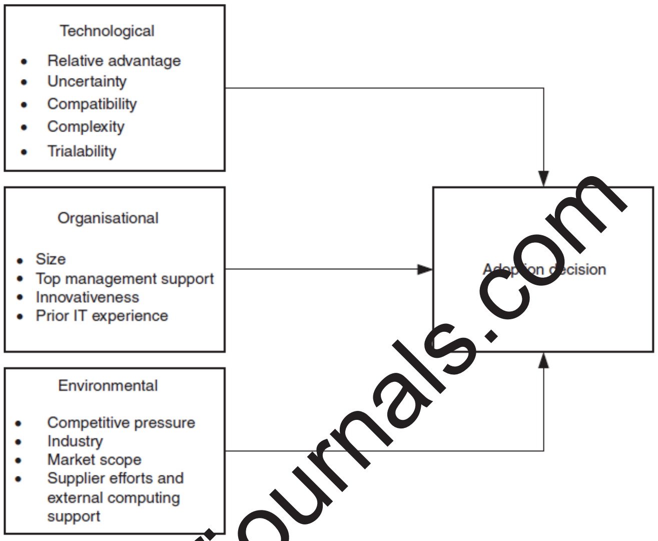
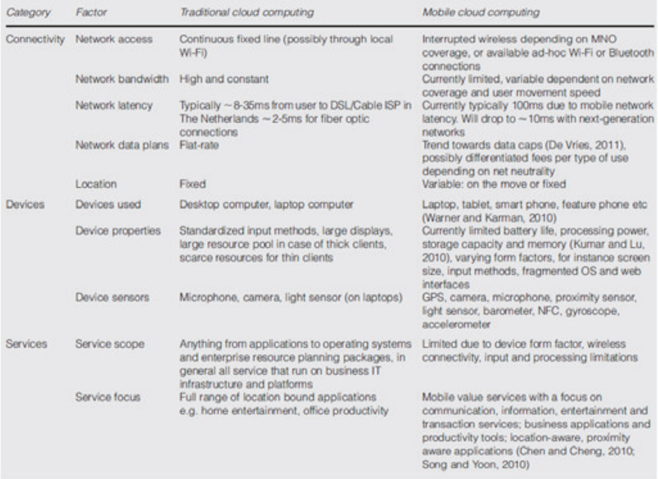


Fig. 10. Framework for SME Adoption of On-demand Computing Services [23]

[25] identifies the prime differences between traditional cloud computing and mobile cloud computing. This is shown in Table 5.

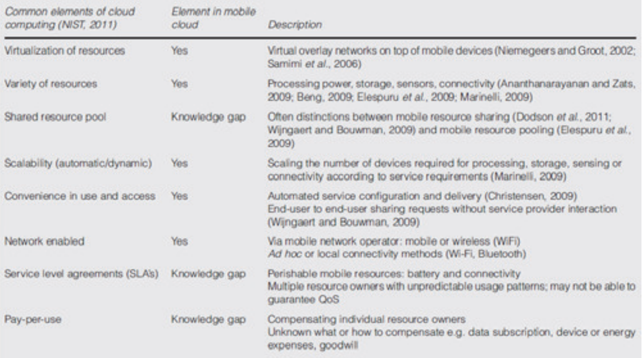
Table 5. Connectivity, Device and Service Differences between Fixed-line Cloud and Mobile Cloud [25]



Category	*Factor*	*Traditional cloud computing*	*Mobile cloud computing*
Connectivity	Network access	Continuous fixed line (possibly through local Wi-Fi)	Interrupted wireless depending on MNO coverage, or available ad-hoc Wi-Fi or Bluetooth connections
	Network bandwidth	High and constant	Currently limited, variable dependent on network coverage and user movement speed
	Network latency	Typically ~8-35ms from user to DSL/Cable ISP in The Netherlands ~2-5ms for fiber optic connections	Currently typically 100ms due to mobile network latency. Will drop to ~10ms with next-generation networks
	Network data plans	Flat-rate	Trend towards data caps (De Vries, 2011), possibly differentiated fees per type of use depending on net neutrality
	Location	Fixed	Variable: on the move or fixed
Devices	Devices used	Desktop computer, laptop computer	Laptop, tablet, smart phone, feature phone etc (Warner and Karman, 2010)
	Device properties	Standardized input methods, large displays, large resource pool in case of thick clients, scarce resources for thin clients	Currently limited battery life, processing power, storage capacity and memory (Kumar and Lu, 2010), varying form factors, for instance screen size, input methods, fragmented OS and web interfaces
	Device sensors	Microphone, camera, light sensor (on laptops)	GPS, camera, microphone, proximity sensor, light sensor, barometer, NFC, gyroscope, accelerometer
Services	Service scope	Anything from applications to operating systems and enterprise resource planning packages, in general all service that run on business IT infrastructure and platforms	Limited due to device form factor, wireless connectivity, input and processing limitations
	Service focus	Full range of location bound applications e.g. home entertainment, office productivity	Mobile value services with a focus on communication, information, entertainment and transaction services; business applications and productivity tools; location-aware, proximity aware applications (Chen and Cheng, 2010; Song and Yoon, 2010)

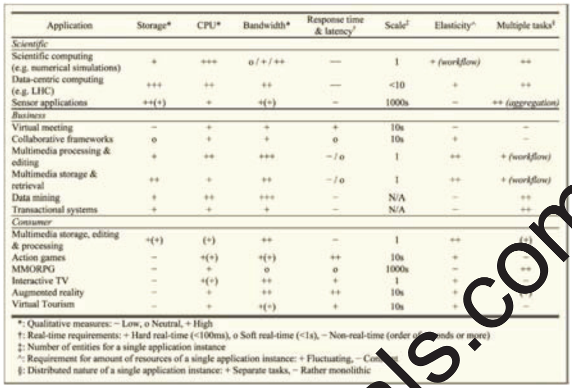
Table 6, highlights the common elements of cloud computing which is applicable to Mobile Cloud Computing resources.

Table 6. Common Elements of Cloud Computing Applied to Mobile Cloud Resources [25]



Common elements of cloud computing (NIST, 2011)	*Element in mobile cloud*	*Description*
Virtualization of resources	Yes	Virtual overlay networks on top of mobile devices (Niemegeers and Groot, 2002; Samimi *et al.*, 2006)
Variety of resources	Yes	Processing power, storage, sensors, connectivity (Ananthanarayanan and Zats, 2009; Beng, 2009; Elespuru *et al.*, 2009; Marinelli, 2009)
Shared resource pool	Knowledge gap	Often distinctions between mobile resource sharing (Dodson *et al.*, 2011; Wijngaert and Bouwman, 2009) and mobile resource pooling (Elespuru *et al.*, 2009)
Scalability (automatic/dynamic)	Yes	Scaling the number of devices required for processing, storage, sensing or connectivity according to service requirements (Marinelli, 2009)
Convenience in use and access	Yes	Automated service configuration and delivery (Christensen, 2009) End-user to end-user sharing requests without service provider interaction (Wijngaert and Bouwman, 2009)
Network enabled	Yes	Via mobile network operator: mobile or wireless (WiFi) *Ad hoc* or local connectivity methods (Wi-Fi, Bluetooth)
Service level agreements (SLA's)	Knowledge gap	Perishable mobile resources: battery and connectivity Multiple resource owners with unpredictable usage patterns; may not be able to guarantee QoS
Pay-per-use	Knowledge gap	Compensating individual resource owners Unknown what or how to compensate e.g. data subscription, device or energy expenses, goodwill

Table 7 Requirements for Novel Applications [24]



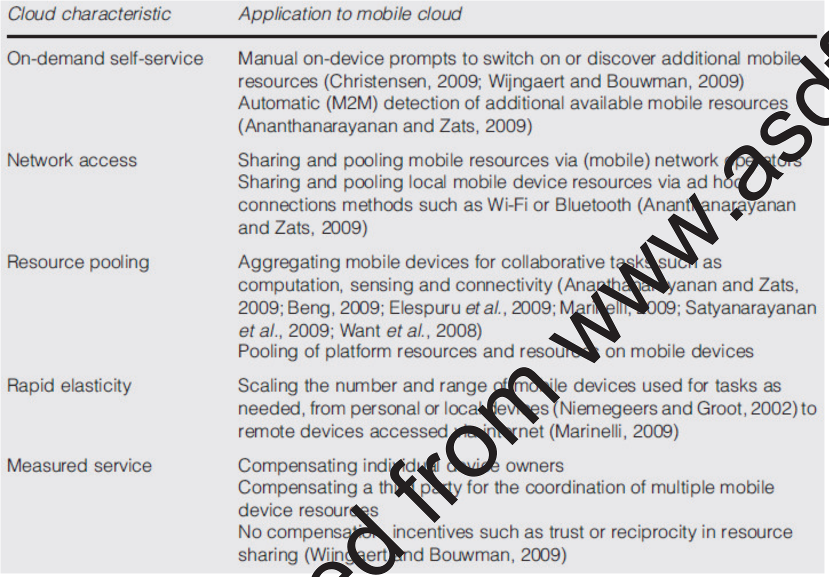
Application	Storage*	CPU*	Bandwidth*	Response time & latency†	Scale‡	Elasticity^	Multiple tasks§
Scientific							
Scientific computing (e.g. numerical simulations)	+	+++	o / + / ++	—	1	+ *(workflow)*	++
Data-centric computing (e.g. LHC)	+++	++	++	—	<10	+	++
Sensor applications	++(+)	+	+(+)	–	1000s	–	++ *(aggregation)*
Business							
Virtual meeting	–	+	+	+	10s	–	–
Collaborative frameworks	o	+	+	o	10s	+	–
Multimedia processing & editing	+	++	+++	– / o	1	++	+ *(workflow)*
Multimedia storage & retrieval	++	+	++	– / o	1	++	+ *(workflow)*
Data mining	+	++	+++	–	N/A	–	++
Transactional systems	+	+	+	–	N/A	–	++
Consumer							
Multimedia storage, editing & processing	+(+)	(+)	++	–	1	++	(+)
Action games	–	+(+)	+(+)	++	10s	+	–
MMORPG	–	+	o	o	1000s	–	++
Interactive TV	–	+(+)	++	+	1	+	–
Augmented reality	–	+	++	++	10s	+	(+)
Virtual Tourism	–	+	+(+)	+	10s	+	–

*: Qualitative measures: – Low, o Neutral, + High
†: Real-time requirements: + Hard real-time (<100ms), o Soft real-time (<1s), – Non-real-time (order of seconds or more)
‡: Number of entities for a single application instance
^: Requirement for amount of resources of a single application instance: + Fluctuating, – Constant
§: Distributed nature of a single application instance: + Separate tasks, – Rather monolithic

Table 7 shows the requirements for novel applications over cloud computing with particular attention to the important factor of elasticity of resources.

Finally Table 8 from [25] shows the essential characteristics which needs to be carefully scrutinised before the migration to cloud services.

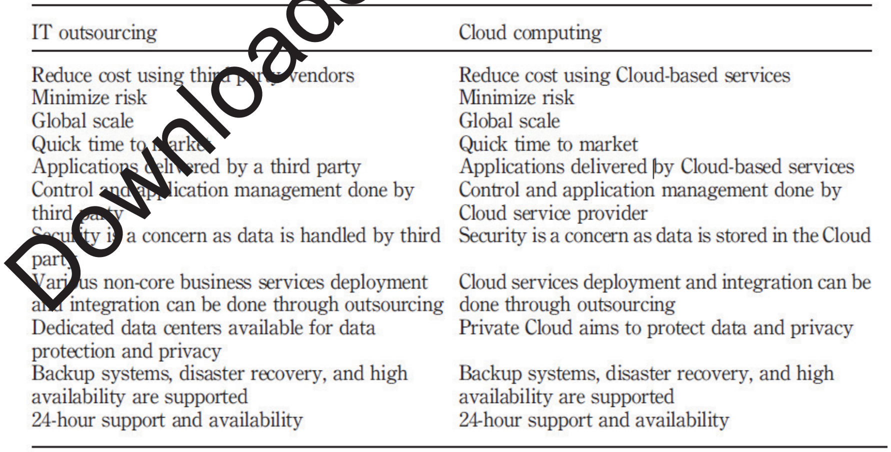
Table 8. Essential Characteristics Based on Mobile Cloud Resources [25]



Cloud characteristic	*Application to mobile cloud*
On-demand self-service	Manual on-device prompts to switch on or discover additional mobile resources (Christensen, 2009; Wijngaert and Bouwman, 2009) Automatic (M2M) detection of additional available mobile resources (Ananthanarayanan and Zats, 2009)
Network access	Sharing and pooling mobile resources via (mobile) network operators Sharing and pooling local mobile device resources via ad hoc connections methods such as Wi-Fi or Bluetooth (Ananthanarayanan and Zats, 2009)
Resource pooling	Aggregating mobile devices for collaborative tasks such as computation, sensing and connectivity (Ananthanarayanan and Zats, 2009; Beng, 2009; Elespuru *et al.*, 2009; Marinelli, 2009; Satyanarayanan *et al.*, 2009; Want *et al.*, 2008) Pooling of platform resources and resources on mobile devices
Rapid elasticity	Scaling the number and range of mobile devices used for tasks as needed, from personal or local devices (Niemegeers and Groot, 2002) to remote devices accessed via internet (Marinelli, 2009)
Measured service	Compensating individual device owners Compensating a third party for the coordination of multiple mobile device resources No compensation: incentives such as trust or reciprocity in resource sharing (Wijngaert and Bouwman, 2009)

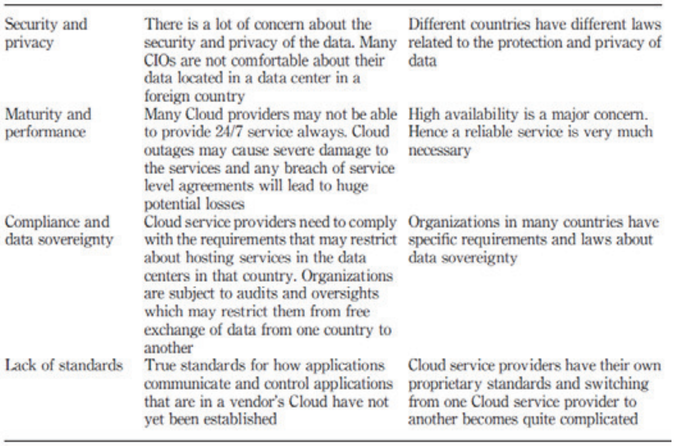
[26] compares global IT outsourcing with Cloud Computing along with the evolution of traditional IT services. The major findings were that the impact of Cloud computing on IT outsourcing is no doubt significant. Cloud computing represents a fundamental shift in how organizations pay for and access IT services. It has created new opportunities for IT services providers and the outsourcing vendors will have to modify their strategy to take advantage of this new computing paradigm. Table 9, shows the similarities between IT outsourcing and Cloud Computing.

Table 9. Some Similarities between IT Outsourcing and Cloud Computing [26]



IT outsourcing	Cloud computing
Reduce cost using third party vendors	Reduce cost using Cloud-based services
Minimize risk	Minimize risk
Global scale	Global scale
Quick time to market	Quick time to market
Applications delivered by a third party	Applications delivered by Cloud-based services
Control and application management done by third party	Control and application management done by Cloud service provider
Security is a concern as data is handled by third party	Security is a concern as data is stored in the Cloud
Various non-core business services deployment and integration can be done through outsourcing	Cloud services deployment and integration can be done through outsourcing
Dedicated data centers available for data protection and privacy	Private Cloud aims to protect data and privacy
Backup systems, disaster recovery, and high availability are supported	Backup systems, disaster recovery, and high availability are supported
24-hour support and availability	24-hour support and availability

Table 10, also shows some challenges faced in the adoption of Cloud Computing.



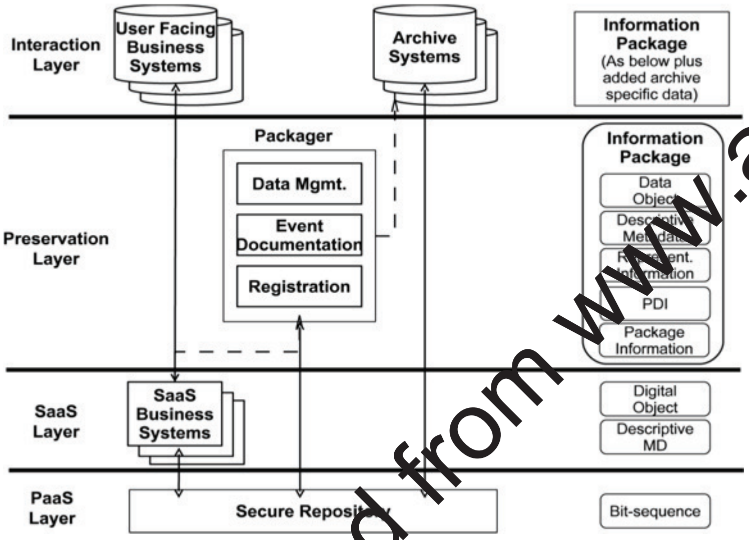
Security and privacy	There is a lot of concern about the security and privacy of the data. Many CIOs are not comfortable about their data located in a data center in a foreign country	Different countries have different laws related to the protection and privacy of data
Maturity and performance	Many Cloud providers may not be able to provide 24/7 service always. Cloud outages may cause severe damage to the services and any breach of service level agreements will lead to huge potential losses	High availability is a major concern. Hence a reliable service is very much necessary
Compliance and data sovereignty	Cloud service providers need to comply with the requirements that may restrict about hosting services in the data centers in that country. Organizations are subject to audits and oversights which may restrict them from free exchange of data from one country to another	Organizations in many countries have specific requirements and laws about data sovereignty
Lack of standards	True standards for how applications communicate and control applications that are in a vendor's Cloud have not yet been established	Cloud service providers have their own proprietary standards and switching from one Cloud service provider to another becomes quite complicated

Table 10. Some Challenges of Cloud Computing [26]

[27] also discusses the current limitations of cloud computing such as security, the absence of service-level agreements, interoperability and lock-in, no scalable storage, latency and network limits and performance instability. The paper concludes by saying that "the cloud is neither good nor bad."

[28] examines the characteristics of managing records in a cloud computing environment and compares these with existing archiving models, exemplified by the open archival information system (OAIS) reference model. The proposed model to preserve records is shown in Fig. 11.

Fig. 11. Information Flow to Preserve Records in Cloud Computing [28]



III. CONCLUSION

This paper has given an overview of the requirements to establish cloud computing. The main model of mobile cloud computing and fixed cloud computing have been covered. Services and their demands and characteristics to ensure a smooth operation over a cloud network have also been discussed. Results have been reported from the literature review. Cloud Computing applications have now rapidly matured and stabilized to offer many services integrated with the mobile communication network.

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